

Appendix A: Carter + Burgess Technical Memorandum on Rail Feasibility

Appendix B: H.W. Lochner Cost Estimates for Berm, Snow Shed, Tunnel, and Road Relocation

Appendix C: Fehr & Peers Technical Memorandum on Traffic Operations Analysis

TECHNICAL MEMORANDUM

Date: August 11, 2006
To: Jon Nepstad, Fehr & Peers
From: Carter & Burgess, Inc.
Subject: Little Cottonwood Canyon Transit Analysis

This memorandum documents the approach used to analyze options for year-round transit service on Utah Highway 210 (Little Cottonwood Canyon Road). A number of factors are considered in comparing the proposed alternatives, but this evaluation primarily focuses on three criteria: passenger capacity, estimated costs, and compatibility in the geographically constrained area. Analysis of each option begins with a qualitative review of system characteristics based on our own project experience or observations of other systems in comparable settings.

This memorandum describes the Little Cottonwood Canyon corridor, presents a range of transit modal options, and establishes a three-tier screening process to identify the most appropriate feasible transit option for Little Cottonwood Canyon.

CORRIDOR BACKGROUND

Little Cottonwood Canyon Road extends almost directly east through the Wasatch Mountains from Wasatch Boulevard at the base of Little Cottonwood Canyon to the Alta ski resort approximately 9 ½ miles up the canyon. Most of the road consists of one travel lane in each direction with left turn pockets at limited locations where there are pullouts or parking areas. Approximately six miles up the canyon, the facility widens to two lanes in the eastern direction for just less than 1 ½ miles to accommodate passing traffic in an area with a steeper grade.

Little Cottonwood Canyon Road provides access for some residential traffic but is largely used to access recreational areas for skiing, hiking, camping, cycling, running and climbing. The road is most heavily used during the winter season when the ski resorts are open. It is estimated that approximately 2,300 people access the road in private vehicles during peak Saturday hours and between 1,400 and 1,600 during peak hours on weekdays. Buses during the ski season are full in the morning and late afternoon hours, carrying between 300 and 500 passengers an hour. It is assumed that any rail transit system would be almost exclusively used by those traveling to and from the ski resorts in the canyon during the winter months and, to a much lesser extent, to and from trailheads for hiking, climbing, cycling, etc. throughout the rest of the year. It is not assumed that residential access or connectivity is a major concern for transit system options on this facility.

RAIL ALTERNATIVES CONSIDERED

Rail and suspended transit system options are evaluated. Options include:

- Maglev
- Heavy Rail
- Commuter Rail
- Monorail
- Cable Liner
- Cog/Rack Railway
- Light Rail Transit/Streetcar
- Funicular
- Aerial Tram

SCREENING PROCESS

The purpose of the screening process is to eliminate transit modes that would be inappropriate in this corridor. Transit modes are deemed appropriate if they:

- Have physical characteristics that allow them to be constructed and operated in the corridor,
- Would meet the capacity needs of the corridor with ridership in the range of comparable projects, and
- Would have capital and operating costs that would likely meet FTA's New Starts criteria.

The screening process includes a two-tier review of the proposed rail transit systems using three primary criteria. These criteria identify the options that are most suitable for service in Little Cottonwood Canyon: physical – compatibility with the geographically constrained corridor, capacity - passenger capacity and potential ridership, and cost effectiveness – capital cost per mile and operating cost per revenue hour.

The first tier screening process includes a qualitative evaluation of the systems based on a general understanding of system characteristics. Several alternatives are clearly not compatible with or feasible on the study corridor. Most were eliminated based on their inability to safely travel the slopes of the roadway which average a 7.3% increase from Wasatch Boulevard to the Alta Ski resort. The rail system alternatives remaining after the first level of screening are carried to the second tier of screening. This step gives a general estimate of costs, infrastructure needs, and service capacity.

SCREENED ALTERNATIVES

First Tier

The following rail systems are eliminated due to obvious limitations in their technology or attributes that make them unsuitable for the corridor area.

Maglev – This technology has often been proposed for extremely frequent and fast operations and is able to relieve air traffic congestion in intercity corridors under 250 miles. It is also proposed for high speed, high capacity point-to-point connectors, such as between major airports and business centers. Maglev speeds approach 200 mph, requiring an alignment with few horizontal or vertical curves, making this technology inappropriate for the steep grades and sharp curves that would be encountered on a surface or aerial alignment in the corridor. Maglev costs exceed \$100 million per mile.

Heavy Rail – This technology is appropriate for very high capacity corridors in dense urban environments. Service typically operates completely separated from streets using electric trains powered by an electrified third rail in the track bed. Heavy rail costs often exceed \$100 million per mile, since aerial and subway sections are often required to avoid any grade crossings with pedestrians or traffic. Heavy rail operates on grades of less than 4%, making this technology unsuitable for the corridor. Urban heavy rail systems operate in Boston, Boston, and New York. Heavy rail systems focused on suburban commuters operate in Atlanta, Miami, and San Francisco.

Commuter Rail – This technology is most commonly operated on tracks shared with the general freight railroad system. The key advantage of this technology is the ability to implement service for a lower capital cost over existing railroad tracks. Service typically operates less frequently over longer distances than other rail modes and often operates only in the peak direction during peak periods. Trains may be locomotive-hauled passenger cars or self-propelled passenger cars, and trains may be powered by diesel or electric engines. Trains operate on grades of less than 4%,

making it inappropriate for operation in this corridor. Where service can be implemented on existing railroad corridors, capital costs may be as low as \$10 million per mile for track and signal improvements, but capital costs in new corridors will be similar to other rail modes.

Monorail – Monorail describes a mode of passenger transit with either single or multi-car trains on an electric runway that can be suspended from or straddling a single beam, rail, or tube. It can be built to require a minimal amount of street-level right of way, virtually negating any conflicts with automobiles, pedestrians, or wildlife and minimizing the need for additional pavement area in the already narrow roadway corridor. Despite its advantages, the maximum grade for monorail is 5%, making it unsuitable in the canyon. This alternative also has very high costs and additional expense would be required for avalanche and wind mitigation.

Light Rail/Streetcar – Light rail transit includes trolleys and streetcars and describes a system of one or more passenger rail cars carrying passengers between major destination centers, usually with multiple stops on a fixed guideway, using electric railway with vehicle power drawn from an overhead catenary. It has the benefit of being a flexible service with the ability to add or remove vehicles as ridership dictates and is able to move through some of the sharper turns in the canyon where necessary. However, the maximum slope for light rail technologies is between 4% and 5% whereas the average slope for the corridor is just over 7%. Trains are capable of running on grades as steep as 8% or 10% and sometimes higher but only for short distances. While light rail could be considered adequate for some areas of the corridor, there are numerous safety issues associated with ascending and descending the canyon, especially while carrying passengers. This alternative is not recommended.

Funicular – Funicular railways typically operate on steep grades for distances as short as a few blocks to no more than two or three miles. This system allows for only two passenger trains, one per direction and typically one car in length. This would not provide the desired service capacity or frequency over such a long corridor.

Second Tier

Rail transit alternatives remaining are more closely evaluated for their costs, capacity, and service features. Table 1 summarizes these characteristics for each alternative. The following alternatives were screened during this step.

Cog (Rack) Railway – This rail system uses a third rail, called a rack rail, that runs center to the two outside rails. A cog wheel on the train meshes to the rack, giving extra traction and allowing the train to surmount even very steep grades in hilly or mountainous areas. Cars are powered with an overhead catenary or diesel unit. This system can be constructed as a dual rack and adhesion system with the transition from two to three rails easily made with the train in motion and as inclines increase. This system could handle the necessary volumes and is the best option for the steep terrain. The overhead catenary would require special attention during inclement weather which could increase the cost of this alternative. Diesel units would not have this problem but could add noise and air impacts.



The Mont Blanc Tramway in France travels 7.7 miles and overcomes an average grade of 15%. 24% maximum.

Cable Liner – The Cable Liner system uses a wire rope to pull small, tram-like cars that sit on standard rail tracks for guidance. It is a relatively new and untested service so any future evaluation of the system as a final alternative for Little Cottonwood Canyon would require a localized assessment of its safety and dependability. However, the apparent operational benefits make it viable as a preliminary alternative. It has a modular design so additional cars can be added to the system as needed. This is an important characteristic as each car holds a limited number of passengers. However, with appropriate systems planning, the Cable Liner has the ability to carry 2,000-3,000 people an hour at speeds just under 30 mph. It is also capable of moving up the steep grades in Little Cottonwood Canyon. It can be constructed as an elevated service, at street level, or below ground or in a tunnel.



Each Doppyelmayr car is fully automated and able to achieve grade increases of 10%.

Aerial Tramway – An aerial tramway is an electric system of aerial cables that carry and propel suspended passenger vehicles. The vehicles range in sizes and passenger capacity and can either stay locked on a fixed cable making point-to-point trips or can loop for more continuous service. Trams are capable of transporting people through very steep areas over relatively long distances and can be built for direct trips with stopping at the end stations only or with intermediate stops. Passenger capacity is limited but can reach between 3200-4000 passengers an hour or more. Speeds are also variable but range between 9 and 27 miles per hour depending on the number of cars and stations. There are some distance concerns with this alternative. Few tramways span a distance of greater than four miles; however services do exist that are over seven and eight miles.



Aerial tramway in Norsjö, Sweden carries passengers almost 8.2 miles



Sandia Peak aerial tramway in Albuquerque, New Mexico travels 2.7 miles with an elevation gain of nearly 4000 feet in 15 minutes.

TABLE 1: COMPARISON OF TRANSIT SYSTEM TECHNOLOGIES

TECHNOLOGY OPTIONS		TYPICAL SYSTEM COSTS		TYPICAL FEATURES			
System	Guideway	Capital (millions/mile)	Operating (millions/year)	Speed (mph)	Grade Limitation	Power Source	Vehicle Capacity
COG/Rack Railway	Track	\$20 - \$60 mil	\$1.0 - \$2.0 mil	15-35	25% - 48%	Steam/Diesel/ Electric	100-200
Cable Liner ^{1,2}	Track	\$15 - \$50 mil	\$.5 - \$1.5 mil	20-25	10% - 15%	Electric	30-33
Aerial Tramway ³	Hanging	\$10 - \$25 mil	\$.8 - \$1.0 mil	9-27		Electric	160

Sources: ¹ <http://www.dcc.at/deutsch/cableliner/cableliner.html>; ² <http://www.dcc.at/default.asp?pid=41>; ³ <http://www.doppelmayr.com/>

SYSTEMS FEATURES

Parking

Parking demand is variable by season with the greatest demand during the winter ski season, typically between November and May. Between 2,600 and 2,800 people travel up the canyon during weekend a.m. peak hours (8-9a.m.) and down during the p.m. peak hour (4-5p.m.) Approximately 2,300 travel by personal vehicle and 300-500 by public transportation. Buses operate on limited schedules during the ski season and are typically full in the morning and late afternoon hours.

Two designated parking lots are located in the canyon. The Little Cottonwood Canyon Park and Ride lot is approximately 1.5 miles east of the Wasatch Boulevard intersection. This lot is open to all drivers year-

round and accommodates bus service during the ski season. The next designated parking area is a little more than five miles up the canyon and is used by climbers, hikers, bikers, joggers, snowshoers, and back country skiers but is not a transit stop. A number of other pullouts exist along the roadway but hold few vehicles and have very little potential of expanding without major excavation of the mountainside.

With the implementation of any new transit service in the canyon, it is likely that additional parking areas will need to be constructed at one or more locations near the convergence of Wasatch Boulevard and Little Cottonwood Road unless high frequency feeder services are implemented throughout the Wasatch Front region. However, it is unlikely that passengers with recreation gear will be apt to take transit where one or more transfers are required.

Any parking area should be able to accommodate a station on site. Otherwise, it is recommended that there be a shuttle service between the parking lot and the station.

Stations

A minimum of two stations will be necessary. Each end of the line stop should have a full station with passenger information and scheduling and covered waiting areas. Intermediate stations are feasible for all alternatives but are most likely for the Cog/Rack Railway and the Cable Liner. Intermediate stations for an Aerial Tramway require towers and the ability to safely move passengers to the street level in addition to coordinated stopping times with the other vehicles sharing the loop cable. While the Cable Liner generally runs on elevated tracks, it can be guided into a raised platform for easy loading and does not require a station tower.

Staging Areas

Several factors determine the appropriate staging area for rail transit vehicles. The primary limitation is the ability to move or transfer the rail and cable cars from their fixed alignments (this is not possible with an aerial tramway). Additionally, the topographic and geographic constraints further limit options for a spur or switched track. Therefore, it is recommended that a staging area be sited at each end of the line station. These areas are recommended as a holding area for out of service transit vehicles but should also have the ability to service idle vehicles to ensure that minimal disruption to service occurs in cases of system or vehicle problems. The exact locations will require a more thorough environmental analysis and coordination with public and private land agencies. Although two staging areas are most appropriate for the narrow and constrained corridor, it is recommended that one central location be sited for a primary staging area, storage and maintenance facility, and control center.

TABLE 2: COMPARISON OF TRANSIT SYSTEM CHARACTERISTICS

	COG RAILWAY	CABLE LINER	AERIAL TRAM
SPEED AND CAPACITY			
Vehicle status during loading/unloading	Fully stopped;	Moving .92 ft/second (standard)	Moving .92 feet/second
Loading/unloading time	Determined by scheduling	10-15 seconds (standard) 20-30+ seconds for ski service	10-15 seconds (standard) 20-30 seconds for ski service
Intermediate stops	Yes	Yes	Possible but less practical or easy compared to other alternatives
Flexibility to increase capacity	Yes	Yes	Yes
Flexibility to expand/extend the system	Yes	Yes	No
ALIGNMENTS			
Tunnel, covered shed or berms allowed?	Yes	Yes	No
Horizontal alignment	Moderate to Low	Low; designed for 165 ft radius; min 98 ft with lower speeds	Straight only
Can travel steep slopes and grades	Yes	About 10% for a standard design	Yes
Space requirements	High	Can be varied with double or single tracks	High
Pedestrian crossing	Signal warnings / cross bars	Signal warnings	N/A
Terminals	Longer terminals if cars are added; multiple loading	Shorter terminals due to continuous movement of passengers; garage required for cars.	Shorter terminals due to continuous movement of passengers; garage required for cars.
SYSTEMS OPERATIONS			
Automation level	Needs a driver	System Supervision recommended	Systems Control required
Vulnerability to winds	None	None	Slower speeds or closure required
Snow and Ice	Little to None	Little to None	None
Emergency Rescue	Easily accessible	Easily Accessible	Difficult
QUALITY OF SERVICE TO RIDERS			
Station Comfort	Moderate to Low; headways are not as flexible – no loop service without “figure 8” track switches	Moderate; shorter waiting time if all cars are in operation	Moderate; shorter waiting time if all cars are in operation
Vehicle Comfort	High; large and flexible seating and storage capacity	Moderate	Moderate to low; small seating and storage capacity
Safety	High	No car attendant	No car attendant
Disabled Access	Yes	Very limited stopping time may not meet ADA requirements	Very limited stopping time may not meet ADA requirements
Heating and Air Conditioning	Yes	Yes	Yes
Public Acceptance	Likely low in this area	New service, unknown	Moderate; some people would be afraid of height
Noise	High	Low	Low
Visual	High	High	High

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SR-210 Little Cottonwood Canyon Transportation Study

Technical Memorandum:

Rough Cost Estimates for Selected Passive Avalanche Control Measures

DATE: May 30, 2006

TO: Ritchie Taylor, UDOT

FROM: Andrea Clayton, H. W. Lochner

CC: Jon Nepstad, Fehr & Peers
Chris Stethem, CSA
file

PROJECT: SR-210 Little Cottonwood Canyon Transportation Study
Project No.: SP-0210(4)4

SUBJECT: Rough Cost Estimates for Passive Avalanche Control Concepts: Berms, Snow Sheds, Roadway Realignment, Staging Areas and Tunnels

The following memorandum addresses rough order of magnitude cost estimates for five different passive avalanche control concepts that could reduce the risk of avalanches reaching SR-210 (Little Cottonwood Canyon Road). The five concepts are:

1. Construction of earth berms adjacent and parallel to the roadway to reduce avalanche runout,
2. Construction of snow sheds to allow avalanches to pass over the roadway,
3. Realignment of the roadway in the mid-canyon section,
4. Widening of staging areas along the roadway to allow for blocked traffic to turn around and clear the Canyon, and
5. Construction of a tunnel for the roadway to avoid avalanche paths.

Little Cottonwood Canyon Road (SR-210): Project No. SP-0210(4)4
Rough Cost Estimates for Avalanche Hazard Reduction Concepts

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1. Introduction

The main objective of the Little Cottonwood Canyon Transportation Study is to improve safety and mobility on SR-210, particularly by reducing the risk associated with avalanches reaching the road while it is open to traffic. There are numerous approaches that could be utilized to reduce the hazard - from increased transit to improved active avalanche control.

This memorandum provides a brief overview and rough cost estimate for five passive control measures:

- Earth berms to reduce avalanche runout
- Snow sheds to pass avalanches over the roadway
- Realignment of the roadway to avoid avalanche paths
- Widening of staging areas to allow traffic to turn around
- Tunnel to avoid avalanche paths.

UDOT contracted with Chris Stethem as part of the Fehr & Peers team to provide avalanche expertise for this study. Coordination with Chris was instrumental in developing design parameters and assumptions for these concepts. All information regarding effectiveness was provided by Chris.

Previous studies have been completed regarding snow sheds (*Recommendations for Design of a Snow Shed: White Pine Avalanche Chutes, Little Cottonwood Canyon, Utah*, Peter Schaerer, 1999) and roadway realignment (*Proposal for State Highway 210 Realignment, Mid-Canyon Section*, Alpentech, Inc., 2004). These studies were also utilized to develop costs.

2. Berm Concept

2.1 Avalanche Berm Overview

One concept that has been proposed as part of this study is to construct berms that could stop small and medium sized avalanches that might occur while the road is open, and prevent them from reaching the road. Berms have been utilized in British Columbia (Roger's Pass, Coquihalla Highway, Kicking Horse Pass), Colorado (I-70 east of Loveland Pass), Alaska (Seward Highway), Europe and Iceland.

Two areas have been identified in Little Cottonwood Canyon where further evaluation of this concept is considered appropriate: White Pine and Little Pine avalanche paths. It is not unusual for avalanche debris to reach the road in these paths, usually when the road is closed for avalanche control work. Several other avalanche paths in the Canyon are also capable of reaching the road. White Pine and Little Pine have been singled out because the terrain in the run out zone is not as steep as in other paths; berm construction is more feasible.

Existing Structure at White Pine

An existing wall/berm structure at White Pine, commonly referred to as the "China Wall", currently offers SR-210 some protection from avalanches. Canyon lore suggests the

structure was built by Chinese laborers in the late 1800's, perhaps as protection for the horse tramway line from avalanches. The front side of this structure (adjacent to the road) is a retaining wall. The backside of the structure is an earthen berm which slopes down to a flat area excavated out of the mountainside. The wall is nearly vertical stacked granite block without mortar or reinforcement.



Front View of “China Wall”

The back side of the wall transitions to an earthen berm which slopes down to a flat excavated area. This area catches the debris of one or two small avalanches, keeping it off the road. The deposited snow must be removed for the berm to be effective for protection against subsequent avalanches. Medium and large avalanche events will overtop the berm and bury the road, particularly on the west end. The wall/berm is tallest on the east end (approximately 20 feet high) and tapers down to nothing approximately 250 feet to the west.



View from behind “China Wall” looking east

Potential Improvements to Existing Structure at White Pine

As mentioned earlier, medium and large avalanche events overtop the existing structure on the west end where the berm height tapers to zero. Increasing the height and extending the berm to the west could increase the level of protection.

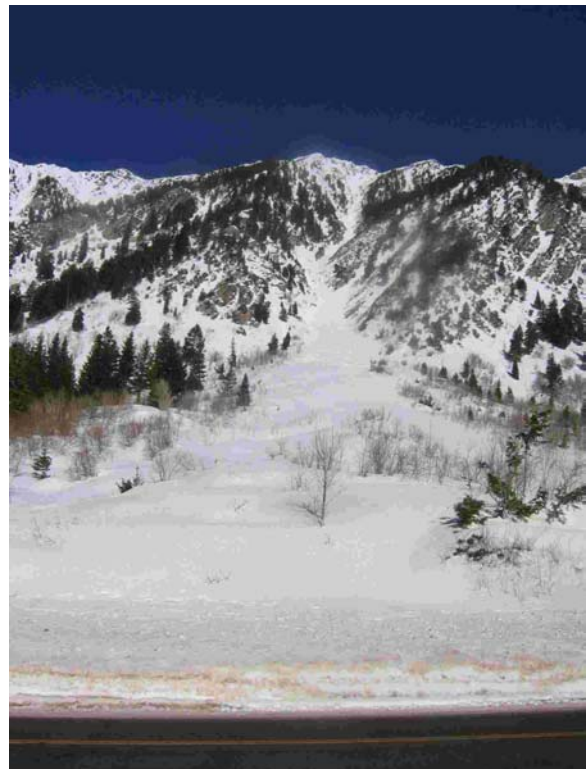
The berms could offer protection from smaller, more frequent avalanches which might occur with the road open. The level of protection a berm could offer is not comparable to the level of protection a structure such as a reinforced concrete snow shed could provide. Avalanches with return intervals varying from 10-100 years would overtop the berms discussed in this memorandum, burying the road with deep snow (greater than 3 feet). Light snow (less than 3 feet) would be expected to overtop a closed road during avalanche control approximately every three years. Generally, snow sheds are designed to withstand forces expected from a 100-year avalanche event.

If berms are used as protective structures, the berm height must be maintained when accumulated avalanche deposits fill in the area above the berm, especially in the centerline of the flow of avalanches.

The west (down canyon) end of the structure should include an opening to allow heavy equipment to push accumulated avalanche debris out of the storage area. The existing structure is open on the west end, with a depressed area available for snow storage. Alternatively, the debris could be placed on top of the berm to increase the height. Over the past several years, UDOT has worked in cooperation with Snowbird to remove deposited avalanche debris with heavy equipment.

Potential Improvements at Little Pine

There is not an existing berm structure at Little Pine. The concept described in this memorandum for Little Pine would be similar to that at White Pine. A berm constructed adjacent to the road with an excavated area behind the berm to catch debris could prevent small avalanches from reaching the road while it is open. Snow removal would be required to maintain effectiveness.



Little Pine Avalanche Path

2.2 Berm Effectiveness

Berm construction as discussed in this memorandum would not prevent all avalanches from reaching the roadway. Some large and fast avalanches would still overtop the berm, but the expected frequency of avalanches reaching the open road would be reduced. The following table, provided by Chris Stethem, shows the estimated reduction in return period (the number of years between avalanche events expected to reach the road) for the scenario where the road is open to traffic.

Return Period for Avalanches Reaching an Open Roadway (years)

Location	Existing Condition		With Berm Improvements	
	Light Avalanches	Deep Avalanches	Light Avalanches	Deep Avalanches
White Pine	15	7.5	15	30
Little Pine	6	15	15	30

Chris estimated the Road Open Hazard Index and the overall Avalanche Hazard Index would be reduced by approximately 11% with the construction of berms at White Pine and Little Pine.

2.3 Right-of-Way

UDOT is in the process of working with the US Forest Service (USFS) to clarify right-of-way for SR-210. Both White Pine and Little Pine are on Forest Service land. Construction activities at these locations will likely require National Environmental Policy Act (NEPA) review and clearance as well as comprehensive coordination with USFS.

2.4 Mapping

The berm concepts discussed in this memorandum are very preliminary. Detailed topographic mapping was not available at the time of this study. Excavation and embankment quantities were estimated from information collected during field reviews and from 1:24,000 USGS Topographic Quadrangle maps.

2.5 Berm Design

Berm dimensions and design criteria discussed in this memorandum are based on recommendations from and discussions with Chris Stethem. There are numerous berm/wall configurations that could be utilized for protection from avalanches. This memorandum describes only one possible scenario to be used for planning purposes. Detailed topographic mapping, geotechnical investigations, supplemental research, and coordination with stakeholders could significantly change the concept should it be progressed to a design phase.

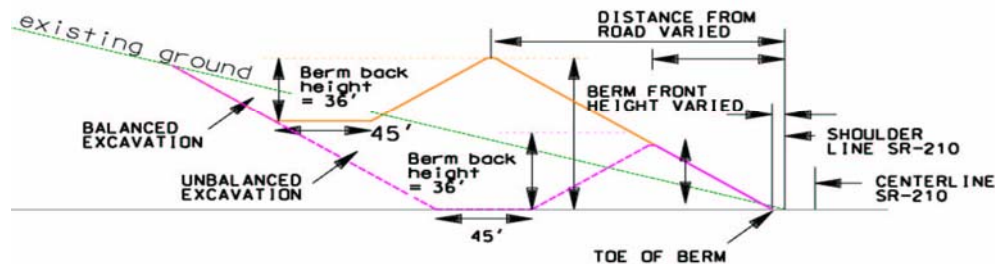
The concept illustrated here assumes excavation and an earthen berm only. A retaining wall could also be incorporated in order to minimize the structure footprint and related impacts; however, cost would increase.

Berm Dimensions

Assumed berm height, length, and width of excavated storage area behind the berm were based on recommendations from Chris Stethem. The recommended height was based on an expected avalanche velocity of 15 m/s (50 ft/s). The recommended length was based on the width of the avalanche run out zone. The width of the storage area was based on both required storage volume and width required to operate snow removal equipment.

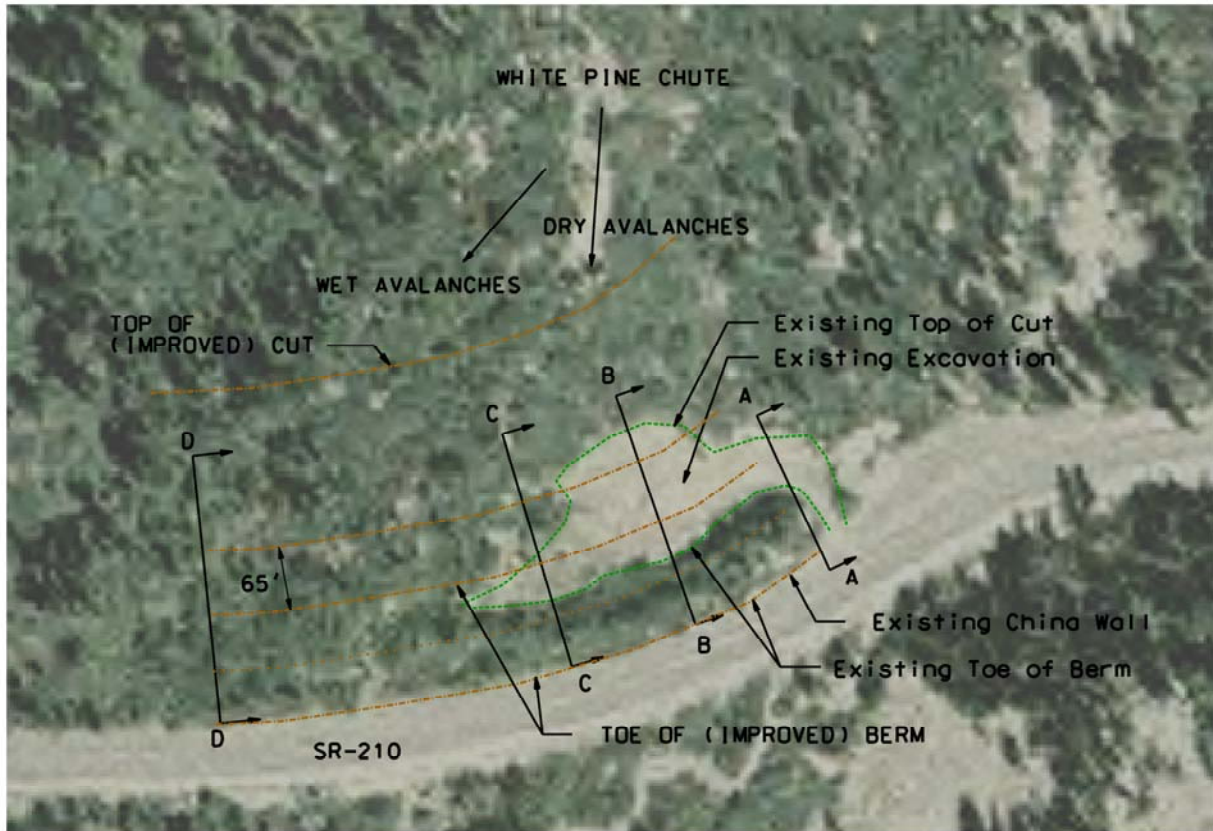
A maximum slope of 1.5 horizontal to 1 vertical was assumed for both berm construction and back slope of the excavated area. This corresponds approximately to existing slopes at the White Pine “China Wall” area. Geotechnical investigations could indicate a steeper slope is possible using native material with slope stabilization.

It was assumed that all of the excavated material could be utilized for berm construction. Expansion of the existing White Pine structure would require more excavation than needed embankment. The configuration of the Little Pine structure was adjusted in order to utilize excess material available from White Pine. The back height of the berm and the width of the excavated storage area were held constant; both the distance from the road to the berm and the front height of the berm were adjusted until the cut and fill volumes until a balance of cut and fill was achieved.



White Pine Berm Configuration

The concept at white pine includes increasing the height of the existing berm to 36 feet and extending the berm and excavation to the west for a total length of 650 feet. The White Pine area was broken into four different sections due to the variability in the existing terrain.

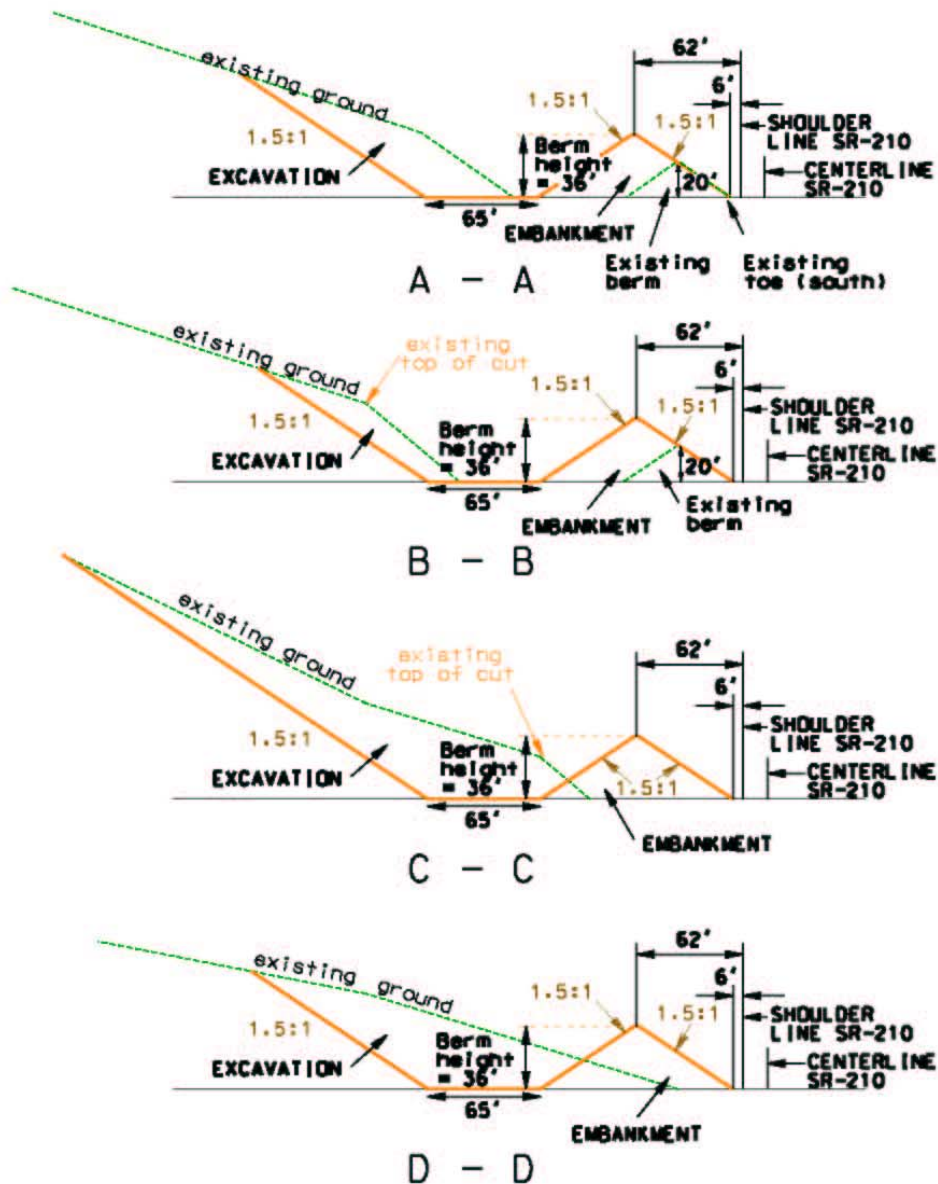


White Pine Plan View

The existing toe of berm on the south side (next to the road) was held constant. A 65 foot flat area for snow storage behind the berm was assumed; this is approximately the existing width on the east end. The berm width at the top was assumed to be 3 feet. The conceptual berm configurations for the four sections at White Pine are shown below.

WHITE PINE BERM CONCEPT

Increase existing berm height.
 extend length to the west
 Hold south toe of berm at edge of roadway
 Excavate 65' flat area behind berm
 Berm height = 36'
 Berm length = 650'
 Berm embankment volume = 38,400 cu yd
 Excavation volume = 111,000 cu yd
 Excess material = 72,600 cu yd
 Storage volume = 103,000 cu yd

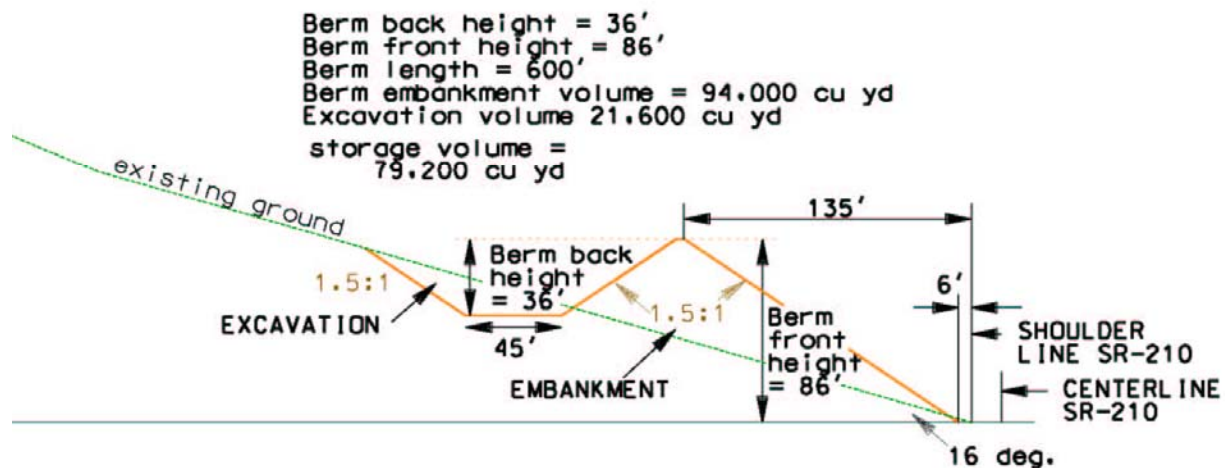


White Pine Sections

Little Pine Berm Configuration

The concept at Little Pine is similar to White Pine. Little Pine was not broken down into different sections because the terrain is fairly consistent in the run out zone. The back height of the berm (where the avalanches would hit) was assumed to be 36 feet. In order to balance the cut and fill volumes utilizing the excess material from Little Pine, the distance from the centerline of the berm to the roadway was adjusted. This resulted in an elevation of the storage area higher than the road. The total berm length was assumed to be 600 feet. The conceptual berm configuration at Little Pine is shown below.

LITTLE PINE BERM CONCEPT



Little Pine Section

2.6 Berm Cost Estimate

For this preliminary cost estimate, only the major cost (excavation) was quantified. The excavation cost includes removal and final placement of the material. Because the needed material for the berms is balanced with the excavated material, there is no cost for embankment. Other costs were estimated using a percentage of the excavation cost. These quantities are direct comparison of areas, and assume that all removed material can be used for embankment. These quantities will be adjusted once geotechnical information is provided.

Quantity Estimate

Estimated quantities are summarized in the table below.

Earthwork Quantity Estimate

	Excavation Volume (cu yd)	Berm Embankment Volume (cu yd)	Excess Material (cu yd)
White Pine	111,020	38,409	72,611
Little Pine	21,556	94,000	-72,444
Total	132,576	132,409	167

Unit Cost for Excavation

The unit cost for excavation was assumed to be \$15 per cubic yard. Unit costs for excavation can be highly variable from one project to another. This unit cost was estimated taking into account the following factors:

- ◆ Average of engineer's estimates and contractor's bids on recent UDOT projects in canyons and mountains near Salt Lake.
 - Provo Canyon: bid in 2004 for 1,381,687 cu yd (\$5.88/cu yd average)
 - Emigration Canyon Bike Lanes: bid in 2005 for 2129 cu yd (\$21.03/cu yd average)
 - Mirror Lake Highway: bid in 2004 for 92 cu yd (\$27/cu yd)
- ◆ Average UDOT bid prices
 - \$8.59/cu yd 2005
 - \$4.46/cu yd 2004
- ◆ Correspondence with individual familiar with excavation in Little Cottonwood Canyon (Paul Garske, UDOT)
 - \$4.20/cu yd for wages, equipment rental, and fuel (does not include profit or overhead)
 - approximately \$12/cu yd assuming 2.8 multiplier for profit and overhead
- ◆ Conversations with local contractors
 - \$8.00/cu yd to \$12/cu yd generally
- ◆ Location specific factors that could drive unit costs up (steep slopes, large boulders in native material, difficult access for large equipment, traffic control)
- ◆ Project specific factors that could drive unit costs down (large excavation quantity, short haul distance from White Pine to Little Pine)

Mobilization

Mobilization was estimated as 10% of the excavation cost.

Misc./Contingency

Smaller construction costs and a contingency to cover unknowns were estimated together as 15% of the excavation cost. Some examples of smaller construction costs could include clearing and grubbing, drainage, traffic control, erosion control, revegetation, etc. Contingency costs could include encountering large boulders or bedrock in excavation, slope failure, etc.

Mitigation

It was assumed that mitigating for environmental consequences could add an additional 15% to project costs. A study undertaken by the Washington State Department of

Transportation (*WSDOT Project Mitigation Costs: Case Studies, 2003*) tracking actual mitigation costs as a percentage of total project costs shows that mitigation can add anywhere from 4% to 34% to total project costs. This study showed a large range in mitigation costs; the average was 15% of the project cost. Project location and setting, and proximity to neighborhoods, streams, and wetlands were determined to be the most critical factors. Although not adjacent to neighborhoods, streams, or wetlands the sensitivity of Little Cottonwood Canyon could drive the mitigation cost up. Thirty percent of the excavation cost was assumed for mitigation. This corresponds to slightly less than 15% of the total estimated project cost.

Potential examples of mitigation could include stone work to blend in with the existing “China Wall” structure, planting mature trees, or other aesthetic treatments.

Environmental Clearance

For cost estimating purposes only, it was assumed that the appropriate level of NEPA documentation would require an Environmental Assessment (EA) and that costs for this level of documentation would be roughly \$500,000. This estimate considers factors such as level of controversy and potential impacts to historic features. Little Cottonwood Canyon is a highly sensitive area and could require considerable public involvement and stakeholder coordination. Furthermore, it is possible the “China Wall” is an historic feature and could require extensive Section 106 coordination with SHPO.

CEI

CEI (Construction Engineering Inspection) was estimated as 10% of the construction cost (mobilization, contingency, mitigation and excavation).

Engineering Design

Engineering Design was estimated as 10% of the construction cost (mobilization, contingency, mitigation and excavation).

Berm Project Cost Estimate

Estimated project costs are summarized in the table below. These unit costs assume the project could be bid in 2006. Assuming a 4% inflation rate per year, this estimate would increase to \$5,108,500 by 2010. It should be noted this estimate is very preliminary and should be used for planning purposes only.

Berm Project Cost Estimate (2005)

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
Mobilization	1	LUMP	\$198,900	\$198,900
Misc./Contingency	1	LUMP	\$298,300	\$298,300
Mitigation	1	LUMP	\$596,600	\$596,600
Roadway Excavation	132,576	C.Y.	\$15	\$1,988,600
			<u>Subtotal</u>	\$3,082,400
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$500,000	\$500,000
CEI Engineering	1	LUMP	\$308,200	\$308,200
Engineering	1	LUMP	\$308,200	\$308,200
			<u>Subtotal</u>	\$1,116,400
PROJECT TOTAL (CURRENT)				\$4,198,800
PROJECT TOTAL (2010)				\$5,108,500

3. Snow Shed Concept

3.1 Snow Shed Overview

Snow sheds are reinforced concrete structures built over the road in avalanche paths. Avalanches pass over the shed without impacting traffic. Snow sheds have been constructed in British Columbia (Roger's Pass, Coquihalla Highway), Washington (I-90 Snoqualmie Pass), Colorado (Red Mountain Pass, Wolf Creek Pass) and the European Alps.

The White Pine Chutes avalanche area consists of four paths (Chute #1 – Chute #4 from east to west). This area is immediately west of the White Pine avalanche path discussed in the berm section. The White Pine Chutes have been identified as a high risk area where a snow shed may be appropriate. A study was conducted by Peter Schaerer in 1999 to make recommendations regarding location and design (*Recommendations for Design of a Snow Shed: White Pine Avalanche Chutes, Little Cottonwood Canyon, Utah*).

The recommendations from the report were:

- Build a 665 foot long snow shed at Chutes #1 and #2
- As a lower priority, extend shed at Chutes #1 and #2 by 220 feet to include Chute #3
- A snow shed is not warranted at Chute #4 because avalanches reach the road infrequently (350 foot extension to shed at Chutes #1-#3).

Cost estimates for these snow shed options are discussed below. Estimates for White Pine and Little Pine are also included for comparison to the berm concept.

3.2 Snow Shed Effectiveness

Snow sheds are generally designed to withstand the forces expected to result from a 100-year avalanche. The risk reduction with snow sheds covering the road was estimated by Chris Stethem for all avalanches (including when the road is closed) as well as for avalanches when the road is open. Both estimates are given below; the first number is the estimate for all avalanches, the second is the estimated reduction in hazard when the road is open:

- White Pine Chutes #1 and #2: 13% and 2%
- White Pine Chutes #1, #2 and #3: 15% and 5%
- White Pine Chutes #1, #2, #3, and #4: 17% and 11%
- White Pine Chutes #1, #2, #3, White Pine, and Little Pine: 31% and 23%
- White Pine Chutes #1, #2, #3, #4, White Pine, and Little Pine: 34% and 29%.

3.3 Right-of-Way

UDOT is in the process of working with the US Forest Service (USFS) to clarify right-of-way for SR-210. There is not currently a clearly defined offset from centerline for UDOT right-of-way. White Pine Chutes, White Pine and Little Pine are all on Forest Service land. Preliminary snow shed studies recommend realigning horizontal curves to tangent sections (as much as possible) in order to improve visibility and ease in design and construction. Coordination with USFS would be required to resolve the right-of-way.

3.4 Snow Shed Design

Design loads for White Pine Chutes are detailed in the 1999 report by Schaerer. A similar analysis was performed for the Power Plant and Dam Chutes in Provo Canyon (*Analysis of Power Plant and Dam Chutes, Provo Canyon, Utah*, David McC Lung and Steven Conger). A snow shed was designed and bid for the Dam Chute avalanche path, although it was excluded from the final construction package. For the cost estimate discussed in this memo, it was assumed the loading for Dam Chute and White Pine Chutes would result in a similar structure. Therefore, the plans and engineer's estimate for Dam Chute were used to extrapolate a cost estimate for the snow shed options in Little Cottonwood Canyon.

It was assumed for this estimate that snow sheds would cover two travel lanes. SR-210 is two lanes (one in each direction) at White Pine Chutes #2, #3, and #4. An uphill passing lane begins to develop at White Pine Chute #1; it was assumed this taper could be shifted to the east if a snow shed were constructed. The roadway is three lanes (one downhill, two uphill) at White Pine and Little Pine. It was assumed only one uphill lane would be protected by a snow shed for the estimates in these two paths; the outside lane would be outside the structure and could be closed when the avalanche hazard was high.

Shed lengths were taken from the 1999 report by Schaerer for White Pine Chutes, and from discussion with Chris Stethem for White Pine and Little Pine:

- White Pine Chutes #1 and #2: 665 feet total
- White Pine Chutes #1, #2 and #3 (additional 220 feet): 885 feet total
- White Pine Chutes #1, #2, #3, and #4 (additional 350 feet): 1235 feet total

- White Pine Chutes #1, #2, #3, White Pine (650 feet), and Little Pine (600 feet): 2135 feet total
- White Pine Chutes #1, #2, #3, #4, White Pine, and Little Pine: 2485 total

Shed lengths could be reduced if directional berms could be constructed up the mountainside in order to funnel avalanches over the center of the shed.

3.5 Snow Shed Cost Estimate

Similar to the method used for the berm concept, only the major cost (shed structure) was quantified. Other project costs were estimated using a percentage of the structure cost.

Unit Cost for Structure

Costs for the snow shed concept were estimated using the design and estimate for the Dam Chute structure in Provo Canyon mentioned above. Costs for snow sheds previously constructed were also investigated for comparison

Dam Chute Snow Shed Cost Estimate

An avalanche shed was designed and bid for UDOT Region 2 in 2003. The design was for a four lane, 130 foot avalanche shed in Provo Canyon to protect SR-189 from the Dam Chute avalanche path (Project No. *NH-0189(12)14). The shed was designed and bid, but never built. The engineer's estimate for Dam Chute was adjusted using more recent unit prices to estimate a current cost per square foot, and cost per linear foot per traffic lane. To extrapolate a cost for the Little Cottonwood Canyon sheds, an excess width similar to what was used for the Dam Chute shed was assumed. This excess width would accommodate curvature of the road, columns, and clearance. The cost adjusted for 2005 unit prices for the Dam Chute shed was estimated at \$178/square foot or \$4,842/linear foot per traffic lane (\$9,684/linear foot for two lanes).

Previously Constructed Snow Sheds

Actual construction costs were available for three existing snow sheds in Canada, Colorado, and Switzerland. These costs were converted to \$U.S. (if necessary), and adjusted to reflect inflated construction costs using the US Army Corps of Engineers Civil Works Construction Cost Index System. This system was developed from historic data to aid in budget preparation purposes, and estimates escalating construction costs from past to present.

1. Great Bear snow shed, Coquihalla Highway, British Columbia, constructed in 1985: total cost was \$14 M (Canadian) for a 220m (722 foot), six lane shed (from Chris Stethem, correspondence 1/12/06). The adjusted cost in current \$U.S. is \$4,093/linear foot per traffic lane, or \$8,186/linear foot for two lanes.
2. East Riverside avalanche shed, Highway 550, Colorado, constructed in 1985: actual cost was \$2.7 M for a 180 foot shed covering two lanes (from *The East Riverside Avalanche Accident of 1992: Engineering and Snow-Safety Considerations*, Arthur Mears, ISSW 1992 Proceedings). The adjusted current cost is \$12,975/linear foot per traffic lane, or \$25,950/linear foot for two lanes). This high cost was attributed to large avalanche loads, inexperience with this type of construction, and a large slope failure during excavation of the cliff east of the shed.

3. Unknown snow shed in Switzerland, constructed in 1999: construction cost was \$14,000/m per lane (from Chris Stethem, correspondence 1/12/6). The adjusted current cost is \$5,248/linear foot per traffic lane, or \$10,496/linear foot for two lanes.

Consideration of these actual construction costs support that estimates extrapolated from the Dam Chute plans and quantities are reasonable. The East Riverside cost was considered extraordinarily high and was not weighed heavily. The cost used for the shed concept discussed in this memorandum for a two lane road was estimated at \$9,700/linear foot (shed construction only) if constructed today.

Mobilization

Mobilization was estimated as 10% of the shed structure cost.

Misc./Contingency

Smaller construction costs and a contingency to cover unknowns were estimated together as 25% of the shed structure cost. Shed lighting costs were investigated and estimated at 4% of the shed cost for fixtures with an initial cost of \$10,000 to connect to a power supply. These are included in the misc./contingency percentage of 25%.

Other examples of smaller construction costs could include drainage behind the shed, traffic control, erosion control, revegetation, etc. Contingency costs could include encountering bedrock in pile driving, slope failure, etc. The misc./contingency percentage is estimated to be higher for the shed than the berm due to complicated traffic control in order to keep the road open, and more complicated design and construction.

Mitigation

Similar to the berm concept, it was assumed that mitigating for environmental consequences could add an additional 15% to project costs. Potential examples of mitigation could include aesthetic treatments for the shed façade or other aesthetic treatments.

Environmental Clearance

For cost estimating purposes only, it was assumed that the appropriate level of NEPA documentation would require an Environmental Assessment (EA) and that costs for this level of documentation would be roughly \$500,000. The same cost was used for the berm concept; it was assumed an environmental document would need to consider both the berm and shed options.

CEI

CEI (Construction Engineering Inspection) was estimated as 10% of the construction cost.

Engineering Design

Engineering Design was estimated as 10% of the construction cost.

Project Cost Estimate

Estimated project costs are summarized in the tables below; there is a separate table for each combination (sheds at different avalanche paths) considered. These unit costs

assume the project could be bid in 2006. It should be noted this estimate is very preliminary and should be used for planning purposes only.

COST ESTIMATES FOR SNOW SHED OPTIONS

White Pine Chutes #1 & #2 Snow Shed Project Cost Estimate

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
Mobilization	1	LUMP	\$645,100	\$645,100
Misc./Contingency	1	LUMP	\$1,612,600	\$1,612,600
Mitigation	1	LUMP	\$1,935,200	\$1,935,200
Snow Shed Structure	665	LIN. FT.	\$9,700	\$6,450,500
			<u>Subtotal</u>	\$10,643,400
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$500,000	\$500,000
CEI Engineering	1	LUMP	\$1,064,300	\$1,064,300
Engineering	1	LUMP	\$1,064,300	\$1,064,300
			<u>Subtotal</u>	\$2,628,600
PROJECT TOTAL (CURRENT)				\$13,272,000
PROJECT TOTAL (2010)				\$16,147,400

White Pine Chutes #1, #2 & #3 Snow Shed Project Cost Estimate

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
Mobilization	1	LUMP	\$858,500	\$858,500
Misc./Contingency	1	LUMP	\$2,146,100	\$2,146,100
Mitigation	1	LUMP	\$2,575,400	\$2,575,400
Snow Shed Structure	885	LIN. FT.	\$9,700	\$8,584,500
			<u>Subtotal</u>	\$14,164,500
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$500,000	\$500,000
CEI Engineering	1	LUMP	\$1,416,500	\$1,416,500
Engineering	1	LUMP	\$1,416,500	\$1,416,500
			<u>Subtotal</u>	\$3,333,000
PROJECT TOTAL (CURRENT)				\$17,497,500
PROJECT TOTAL (2010)				\$21,288,400

**White Pine Chutes #1, #2, #3, & #4
Snow Shed Project Cost Estimate**

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
Mobilization	1	LUMP	\$1,198,000	\$1,198,000
Misc./Contingency	1	LUMP	\$2,994,900	\$2,994,900
Mitigation	1	LUMP	\$3,593,900	\$3,593,900
Snow Shed Structure	1,235	LIN. FT.	\$9,700	\$11,979,500
			<u>Subtotal</u>	\$19,766,300
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$500,000	\$500,000
CEI Engineering	1	LUMP	\$1,976,600	\$1,976,600
Engineering	1	LUMP	\$1,976,600	\$1,976,600
			<u>Subtotal</u>	\$4,453,200
PROJECT TOTAL (CURRENT)				\$24,219,500
PROJECT TOTAL (2010)				\$29,466,700

**White Pine Chutes #1, #2, #3, White Pine & Little Pine
Snow Shed Project Cost Estimate**

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
Mobilization	1	LUMP	\$2,071,000	\$2,071,000
Misc./Contingency	1	LUMP	\$5,177,400	\$5,177,400
Mitigation	1	LUMP	\$6,212,900	\$6,212,900
Snow Shed Structure	2,135	LIN. FT.	\$9,700	\$20,709,500
			<u>Subtotal</u>	\$34,170,800
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$500,000	\$500,000
CEI Engineering	1	LUMP	\$3,417,100	\$3,417,100
Engineering	1	LUMP	\$3,414,100	\$3,414,100
			<u>Subtotal</u>	\$7,334,200
PROJECT TOTAL (CURRENT)				\$41,505,000
PROJECT TOTAL (2010)				\$50,497,200

**White Pine Chutes #1, #2, #3, #4, White Pine & Little Pine
Snow Shed Project Cost Estimate**

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
Mobilization	1	LUMP	\$2,410,500	\$2,410,500
Misc./Contingency	1	LUMP	\$6,026,100	\$6,026,100
Mitigation	1	LUMP	\$7,231,400	\$7,231,400
Snow Shed Structure	2,485	LIN. FT.	\$9,700	\$24,104,500
			<u>Subtotal</u>	\$39,772,500
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$500,000	\$500,000
CEI Engineering	1	LUMP	\$3,977,300	\$3,977,300
Engineering	1	LUMP	\$3,977,300	\$3,977,300
			<u>Subtotal</u>	\$8,454,600
PROJECT TOTAL (CURRENT)				\$48,227,100
PROJECT TOTAL (2010)				\$58,675,600

4. Roadway Realignment Concept

4.1 Roadway Realignment Overview

A preliminary study was conducted by Alpentech, Inc. for Alta Ski Lifts Co. regarding realignment of the mid-canyon section of SR-210 (*Proposal for State Highway 210 Realignment, Mid-Canyon Section, Little Cottonwood Canyon, Salt Lake County*, June 29, 2004). The roadway realignment concept discussed here is based on this report. Because this study is preliminary, and because topographic mapping was not readily available, it was decided to use the Alpentech realignment at a basis for the cost estimate rather than to generate a new alignment.

The section proposed for realignment is between the Old Mill avalanche path on the west and the Willows path on the east. The total length of the proposed realignment is roughly 15,000 feet, or 2.8 miles. It is on the south side of the Canyon, and would require two new crossings of Little Cottonwood Creek.

The proposed realignment would avoid several avalanche paths on the north side that have reached the road: Maybird, Tanner's, White Pine Chutes, White Pine, and Little Pine. However, it would traverse four avalanche paths on the south (north facing) side that do not reach the existing road: Display Ridge, Scotty's Notch, Scotty's Bowl, and Coffin Chute. There is no data regarding these paths in the UDOT database. Both the existing and proposed alignments cross Little Pine East and the Willows avalanche paths.

The criteria Alpentech used for this proposed realignment were to avoid as many avalanche paths as possible and to keep the grade at 10% or less. This proposal

traverses the Lone Peak Wilderness Area. Resistance from the public and interest groups such as Save Our Canyons would be strong.

Other factors for consideration are potential impacts to extremely valuable resources: Little Cottonwood Creek, Riparian Habitat Conservation Areas, and water quality for the watershed. There is concern that moving the road closer to the Creek would jeopardize water quality. Runoff polluted with hydrocarbons and deicing chemicals would have less distance to pass through vegetated areas before reaching the Creek. There would be less opportunity to contain accidental spills. Salt Lake City Corporation would likely resist an alignment adjacent to the Creek.

The north facing slopes (on the south side) do not receive as much sunlight as the south facing slopes (on the north side). The proposed realignment would likely be icier than the existing road. Snow would not melt as quickly, storage could be an issue.

Access to climbing areas is also a factor. If the existing road were restored to a natural condition through the proposed realignment section, access to popular rock climbing and bouldering routes on the north side of the Canyon would be eliminated.

4.2 Realignment Effectiveness

Reduction of the avalanche hazard index when the road is open to traffic with this realignment is estimated at 42% and 51% in consideration of all avalanches (open or closed). (Chris Stethem).

4.3 Right-of-Way

The proposed realignment is on National Forest land. Slightly more than a half mile is proposed through the Lone Peak Wilderness Area. Realignment would require extensive coordination and public involvement. It would require an act of Congress to allow a road in the Wilderness Area. It is possible to develop an alignment that could avoid the Wilderness Area. However, it would bisect the Tanner's Flat Campground, potentially destroying the resource. That alternative is not discussed in this memo.

4.4 Mapping

Standard sources for digital topographic mapping were investigated at the time of this report. Salt Lake County had contours available for a portion of the proposed realignment section, west of White Pine. Alpentech has digital topographic mapping which they are willing to share if they are compensated, appropriate costs were not discussed. Olympus Aerial Surveys, Inc. generated the topo for Alpentech. They are willing to sell it assuming Alpentech gives their permission. Topographic mapping was not obtained for this study. Adjustments to earthwork discussed below were estimated visually using Alpentech's cross sections.

4.5 Roadway Realignment Design

Pavement Section

For this cost estimate, an asphalt pavement section was assumed:

- 1" OGSC (open graded surface course)
- 8" HMA (hot mix asphalt)

- 8" UTBC (untreated base course)
- 19" GB (granular borrow)

Alpentech Study

As noted above, the alignment and grade for the Alpentech study were used as a basis for this cost estimate without modification. However, the typical section was modified to reflect current design standards for this cost estimate. The Alpentech realignment proposal includes the following design elements:

- Two 12-foot travel lanes (no passing lane)
- Two 4-foot shoulders
- Two 4-foot benches sloped away from the shoulder at 4:1
- 1.5 H : 1 V fill slopes, without barrier
- 0.8 H : 1 V to 1.5 H : 1 V cut slopes

The shoulder width, cut ditch, and side slopes do not meet UDOT, AASHTO or Roadside Design Guide Standards. It is unlikely a roadway could be constructed to these standards if constructed today. It is also questionable that cut and fill slopes as steep as 0.8:1 and 1.5:1 would be stable. The cost estimates presented in this memorandum include adjustments to the typical section used by Alpentech.

Cost estimates for two realignment concepts were developed using Alpentech's alignment and grade: 1) modified typical section to meet clear zone requirements without barrier, and 2) modified typical section with barrier. Each is discussed separately below.

Earthwork

Cross sections and earthwork quantities were available at approximate 100-foot intervals in the Alpentech study. Modifications to the quantities were estimated graphically (percentage increase or decrease) from the cross sections.

Modification to Alpentech Study: Passing Lane

The existing road (the section that would be bypassed with realignment) includes an uphill passing lane from White Pine Chute #1 to the east. Both cost estimates presented here include a passing lane for the last mile of realignment (Alpentech station 344+19 to 392+00). This last mile of realignment is relatively straight, it was considered appropriate to include a passing lane in the cost estimate.

Roadway Realignment Option 1: Clear Zone Option

This realignment option reflects modifications to the Alpentech proposal in order to meet Roadside Design Guide clear zone requirements. For a design speed of 40 mph (design speed of existing road) with ADT (average daily traffic) of 7000 vehicles/day, a 14 foot clear zone is recommended at 6:1. This option includes the following modifications to the Alpentech proposal:

- Addition of 12-foot passing lane for nearly one mile
- Shoulder width increased to 6-feet
- Cut ditch per UDOT STD DWG DD 2 (flow line 1-foot below untreated base course layer to drain pavement section)
- Fill slope at 6:1 for 8 feet from pavement to meet 14 foot clear zone (including shoulder)

- Fill slope at 2 H : 1 V maximum (beyond clear zone)
- Cut slope at 2 H : 1 V maximum
- Walls where a 2:1 cut slope can not catch existing ground

Roadway Realignment Option 2: Barrier Option

This realignment option is also based on the Alpentech proposal - modified to include barriers where the side slope is steeper than 4 H : 1 V. This option would reduce grading impacts compared to the clear zone option. However, barriers create problems with snow removal and in avalanche areas. Another issue related to barrier use is drainage; a storm drain and associated water quality treatment system would be necessary. This option includes the following modifications to the Alpentech proposal:

- Addition of 12-foot passing lane for nearly one mile
- Shoulder width increased to 6-feet
- Barrier where clear zone standards are not met (slope steeper than 4 H : 1 V)
- Fill slope at 2 H : 1 V maximum (behind barrier)
- Cut slope at 2 H : 1 V maximum
- Walls where a 2:1 cut slope can not catch existing ground

Even though less earth work is required for the barrier option, it is more expensive than the clear zone option. The pavement would be wider to support barrier, and a storm drain system would be required to manage drainage.

4.6 Roadway Realignment Cost Estimate

For this preliminary cost estimate, only the major costs (structures, pavement, walls, earthwork, storm drain) were quantified. Other costs were estimated using a percentage of the excavation cost.

Unit Costs

Unit costs were estimated taking into consideration current average bid prices and recent projects in canyon environments near Salt Lake. Unit costs assumed are shown in the cost estimate table at the end of this section. Following is a brief explanation regarding the unit costs assumed for some of the major items:

- ♦ Unit cost for roadway excavation was assumed to be \$18/cubic yard – slightly higher than what was assumed for the berm concept because more hauling would be necessary.
- ♦ Unit cost for structures was assumed to be \$275/square foot. This cost is for a single span box girder or arch span. Based on conversations with Salt Lake City Public Utilities, it was assumed a clear span would be required to protect Little Cottonwood Creek. Water quality is critical in Little Cottonwood Canyon because the watershed provides drinking water to Salt Lake City. The Salt Lake City-County Health Department maintains a strict 50- foot building setback from the Creek. Riparian Habitat Conservation is also crucial in the Canyon. The Forest Service has established Riparian Habitat Conservation Areas (RHCAs); a 300 foot buffer surrounds active fish bearing streams such as Little Cottonwood Creek.
- ♦ Unit cost for retaining walls was assumed to be \$60/square foot (face of wall). Many of the walls are to minimize excavation into the mountain side, and would be required to withstand substantial pressure.

Mobilization

Mobilization was estimated as 10% of the roadway cost.

Misc./Contingency

Smaller construction costs and a contingency to cover unknowns were estimated together as 25% of the roadway cost. Some examples of smaller construction costs could include clearing and grubbing, drainage (although storm drain is quantified for the barrier option), traffic control, erosion control, revegetation, etc. Contingency costs could include encountering large boulders or bedrock in excavation, slope failure, etc.

Mitigation

It was assumed that mitigating for environmental consequences could add an additional 20% to project costs. A higher percentage was assumed for the realignment concept compared to the berm or shed concept because impacts would be greater with two additional stream crossings and associated wetlands impacts. Fifty percent of the roadway cost was assumed for mitigation; this corresponds to roughly 20 % of the project cost.

Potential examples of mitigation could include aesthetic treatment for structures and walls, restoration of the existing road to a natural condition, wetland mitigation, planting mature trees, or other aesthetic treatments.

Environmental Clearance

For cost estimating purposes only, it was assumed that the appropriate level of NEPA documentation would require an Environmental Impact Statement (EIS) and that costs for this level of documentation would be roughly \$5 Million. The Washington State Department of Transportation has tracked actual costs for environmental documentation since 2002. The costs for Final Environmental Impact Statements range from \$1.2 million to \$7.5 million, the average cost is just over \$4 Million. Because this realignment option traverses the Lone Peak Wilderness Area, it would require an act of Congress to change the wilderness boundaries (wilderness is by definition road less). If the proposed realignment were shifted to avoid the Wilderness Area, it would be necessary to bisect the Tanner's Flat Campground, destroying the resource. Little Cottonwood Canyon is a highly sensitive area and could require considerable public involvement and stakeholder coordination. Realignment would be highly controversial.

CEI

CEI (Construction Engineering Inspection) was estimated as 10% of the construction cost.

Engineering Design

Engineering Design was estimated as 10% of the construction cost.

Realignment Project Cost Estimate

Estimated project costs for both the clear zone and barrier options are summarized in the table below. It should be noted this estimate is very preliminary and should be used for planning purposes only.

Realignment Project Cost Estimate (2005)
Clear Zone Option

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
ROADWAY				
Mobilization	1	LUMP	\$1,894,200	\$1,894,200
Misc./Contingency	1	LUMP	\$4,735,600	\$4,735,600
Mitigation	1	LUMP	\$9,471,200	\$9,471,200
Borrow	684	TON	\$15	\$10,300
Granular Borrow	120,023	TON	\$18	\$2,160,400
Roadway Excavation	189,957	C.Y.	\$18	\$3,419,200
Untreated Base Course	42,840	TON	\$18.25	\$781,800
Hot Mix Asphalt	31,002	TON	\$56	\$1,736,100
Open Graded Surface Course	3,848	TON	\$80	\$307,900
Crash Cushion – Type F	10	EACH	\$7,800	\$78,000
STRUCTURES				
Granular Backfill Borrow	19,470	C.Y.	\$70	\$1,362,900
Retaining Wall	36,525	SQ. FT.	\$60	\$2,191,500
Retaining Wall-Moment Slab	1,579	C.Y.	\$500	\$789,300
Bridge	22,200	SQ. FT.	\$275	\$6,105,000
			<u>Subtotal</u>	\$35,043,400
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$5,000,000	\$5,000,000
CEI Engineering	1	LUMP	\$3,504,300	\$3,504,300
Engineering	1	LUMP	\$3,504,300	\$3,504,300
			<u>Subtotal</u>	\$12,008,600
PROJECT TOTAL (CURRENT)				\$47,052,000
PROJECT TOTAL (2010)				\$57,246,000

Realignment Project Cost Estimate (2005)
Barrier Option

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
ROADWAY				
Mobilization	1	LUMP	\$2,073,500	\$2,073,500
Misc./Contingency	1	LUMP	\$5,183,700	\$5,183,700
Mitigation	1	LUMP	\$10,367,400	\$10,367,400
Borrow	517	TON	\$15	\$7,800
Granular Borrow	127,802	TON	\$18	\$2,300,400
Roadway Excavation	131,116	C.Y.	\$18	\$2,360,100
Untreated Base Course	46,093	TON	\$18.25	\$841,200
Hot Mix Asphalt	34,277	TON	\$56	\$1,919,500
Open Graded Surface Course	4,255	TON	\$60	\$255,300
Precast Concrete Barrier	14,536	FT	\$40	\$581,400
Crash Cushion – Type F	10	EACH	\$7,800	\$78,000
STRUCTURES				
Granular Backfill Borrow	19,470	C.Y.	\$70	\$1,362,900
Retaining Wall	36,525	SQ. FT.	\$60	\$2,191,500
Retaining Wall-Moment Slab	1,579	C.Y.	\$500	\$789,300
Bridge	22,200	SQ. FT.	\$275	\$6,105,000
DRAINAGE				
24" Pipe Culvert	15,283	LIN. FT.	\$95	\$1,451,900
18" Pipe Culvert	2,443	LIN. FT.	\$80	\$195,400
Catch Basin	102	EACH	\$2,500	\$255,000
Oil Water Separator	10	EACH	\$4000	\$40,000
			<u>Subtotal</u>	\$37,956,500
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$5,000,000	\$5,000,000
CEI Engineering	1	LUMP	\$3,835,900	\$3,835,900
Engineering	1	LUMP	\$3,835,900	\$3,835,900
			<u>Subtotal</u>	\$12,671,800
PROJECT TOTAL (CURRENT)				\$51,031,100
PROJECT TOTAL (2010)				\$62,087,100

5. Staging Area Concept

5.1 Staging Area Overview

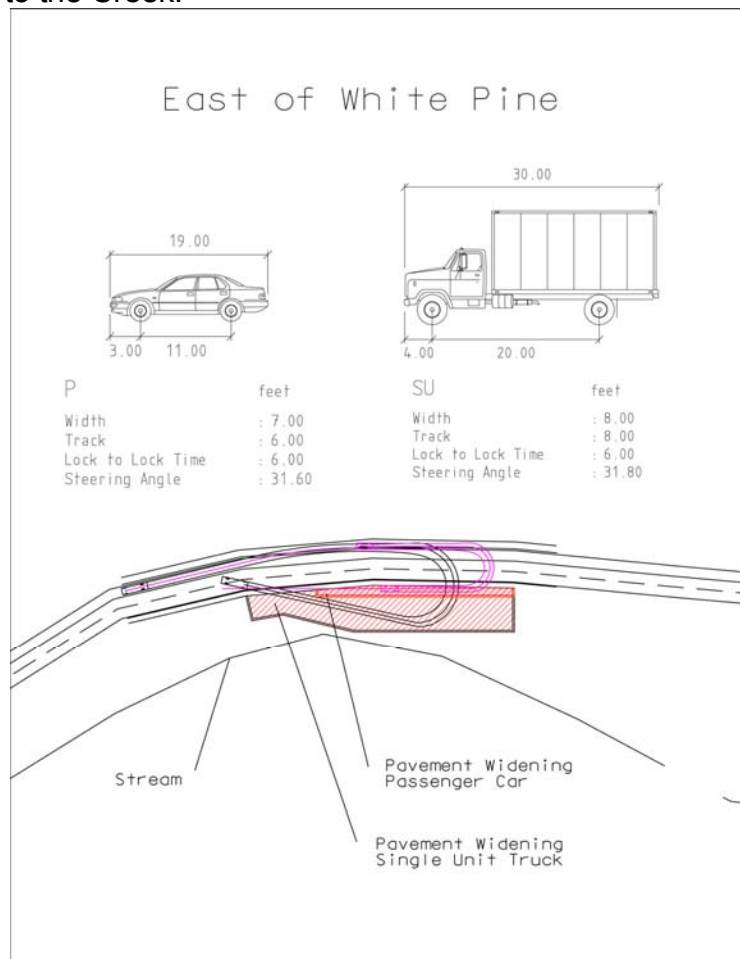
There are certain areas along SR-210 that are designated staging areas, areas considered safe from avalanche. This concept involves widening these staging areas enough to allow cars and trucks to turn around with a single point turn and to provide increased parking for vehicles trapped between avalanche paths. One of the worst case

scenarios for SR-210 is for an avalanche to cover the road when it is open to traffic - then for a line of cars to queue up behind the debris, becoming targets for a subsequent avalanche. In this scenario, it is critical to move traffic off the roadway into safe areas quickly to assess the need for additional control work prior to clearing the road. The process of turning around the vehicles and clearing the hazardous areas could be expedited if there were an area wide enough to make a U turn. The widened areas would also provided additional safe parking for vehicles trapped between avalanche paths.

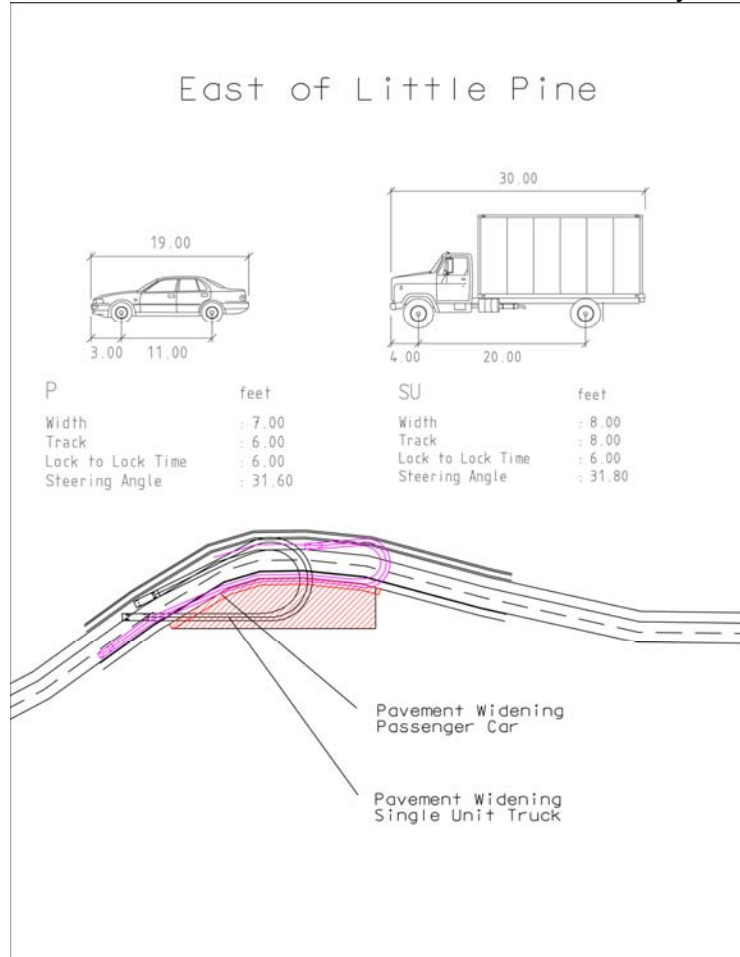
There are nine of these staging areas in Little Cottonwood Canyon, from immediately west of the Maybird path to west of the Cottonwood Draw path. The objective for this memorandum is to determine a range of costs associated with improving a staging area.

Two design vehicles were considered for these estimates: a passenger car (19-feet long by 7-feet wide), and a single axle delivery truck (30-feet long by 8-feet wide). Some vehicles such as buses or larger trucks would have to make multiple point turns.

Two staging areas were selected to develop cost estimates, 1) immediately east of White Pine, and 2) immediately east of Little Pine. The area immediately east of White Pine was selected to represent the higher end of the cost spectrum. At this location, there is a 10 foot drop off very close to Little Cottonwood Creek. Widening would require walls to minimize impacts to the Creek.



The area immediately east of Little Pine was selected to represent the lower end of the cost spectrum. The terrain on the south side of the road is relatively flat at this location.



5.2 Staging Area Effectiveness

Improving the staging areas could reduce the avalanche risk to traffic on the roadway by an estimated 5% (Chris Stethem). This assumes the waiting time to clear traffic from the hazardous areas is reduced from 60 to 55 minutes, following a natural avalanche blocking the road.

5.3 Right-of-Way

UDOT is in the process of working with the US Forest Service (USFS) to clarify right-of-way for SR-210. There is not currently a clearly defined offset from centerline for UDOT right-of-way. Coordination with USFS would be required to resolve the right-of-way.

5.4 Mapping

Preliminary cost estimates for improving staging areas were developed without detailed topographic mapping. Some information was available in *Big and Little Cottonwood Canyons – Spot Safety Study (Project No. STP-9999(801))* by HNTB, June 2005. USGS topographic quadrangle maps were also referenced.

5.5 Staging Area Design

Pavement Section

For this cost estimate, an asphalt pavement section was assumed (the same pavement section assumed in the realignment concept):

- 1" OGSC (open graded surface course)
- 8" HMA (hot mix asphalt)
- 8" UTBC (untreated base course)
- 19" GB (granular borrow)

Pavement Dimensions

Auto Turn software was used to determine the width (and length of widening) required to turn around the two design vehicles at the two staging area locations mentioned (east of White Pine and east of Little Pine).

5.6 Staging Area Cost Estimate

For this preliminary cost estimate, only the major roadway construction costs (pavement, earthwork, walls) were quantified. The unit costs for the staging area concept are the same that were used for the realignment concept. Other costs were estimated as a percentage of these major construction costs.

Mobilization

Mobilization was estimated as 10% of the roadway cost.

Misc./Contingency

Smaller construction costs and a contingency to cover unknowns were estimated together as 15% of the roadway cost. Some examples of smaller construction costs could include clearing and grubbing, drainage, traffic control, erosion control, revegetation, etc. Contingency costs could include encountering springs, large boulders or bedrock in excavation, etc.

Mitigation

It was assumed that mitigating for environmental consequences could add an additional 15% to project costs.

Potential examples of mitigation could include aesthetic treatment for walls, wetland mitigation, planting mature trees, or other aesthetic treatments.

Environmental Clearance

For cost estimating purposes only, it was assumed that the appropriate level of NEPA documentation would require a Categorical Exclusion (CE) and that costs for this level of documentation would be roughly \$100,000. Little Cottonwood Canyon is a highly sensitive area and could require considerable public involvement and stakeholder coordination. Proximity to Little Cottonwood Creek could also increase the cost.

CEI

CEI (Construction Engineering Inspection) was estimated as 10% of the construction cost.

Engineering Design

Engineering Design was estimated as 10% of the construction cost.

Staging Area Project Cost Estimate

Estimated project costs for four staging area options are summarized in the tables below. It should be noted this estimate is very preliminary and should be used for planning purposes only.

Staging Area Project Cost Estimate (2005) East of White Pine (Passenger Car) Option

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
ROADWAY				
Mobilization	1	LUMP	\$32,100	\$32,100
Misc./Contingency	1	LUMP	\$48,200	\$48,200
Mitigation	1	LUMP	\$105,900	\$105,900
Borrow	981	TON	\$15	\$14,700
Granular Borrow	319	TON	\$18	\$5,700
Untreated Base Course	134	TON	\$18.25	\$2,400
Hot Mix Asphalt	134	TON	\$56	\$7,500
Open Graded Surface Course	17	TON	\$80	\$1,300
STRUCTURES				
Granular Backfill Borrow	741	C.Y.	\$70	\$51,900
Retaining Wall	2,500	SQ. FT.	\$60	\$150,000
Retaining Wall-Moment Slab	175	C.Y.	\$500	\$87,500
			<u>Subtotal</u>	\$507,200
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$100,000	\$100,000
CEI Engineering	1	LUMP	\$50,700	\$50,700
Engineering	1	LUMP	\$50,700	\$50,700
			<u>Subtotal</u>	\$201,400
PROJECT TOTAL (CURRENT)				\$708,600
PROJECT TOTAL (2010)				\$862,100

**Staging Area Project Cost Estimate (2005)
East of White Pine (Single Unit Truck) Option**

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
ROADWAY				
Mobilization	1	LUMP	\$62,900	\$62,900
Misc./Contingency	1	LUMP	\$94,300	\$94,300
Mitigation	1	LUMP	\$188,600	\$188,600
Borrow	5111	TON	\$15	\$76,700
Granular Borrow	1,663	TON	\$18	\$29,900
Untreated Base Course	696	TON	\$18.25	\$12,700
Hot Mix Asphalt	700	TON	\$56	\$39,200
Open Graded Surface Course	87	TON	\$80	\$7,000
STRUCTURES				
Granular Backfill Borrow	1,185	C.Y.	\$70	\$83,000
Retaining Wall	4,000	SQ. FT.	\$60	\$240,000
Retaining Wall-Moment Slab	280	C.Y	\$500	\$140,000
			<u>Subtotal</u>	\$974,300
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$100,000	\$100,000
CEI Engineering	1	LUMP	\$97,400	\$97,400
Engineering	1	LUMP	\$97,400	\$97,400
			<u>Subtotal</u>	\$294,800
PROJECT TOTAL (CURRENT)				\$1,269,100
PROJECT TOTAL (2010)				\$1,544,100

**Staging Area Project Cost Estimate (2005)
East of Little Pine (Passenger Car) Option**

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
ROADWAY				
Mobilization	1	LUMP	\$3,300	\$3,300
Misc./Contingency	1	LUMP	\$5,000	\$5,000
Mitigation	1	LUMP	\$26,500	\$26,500
Borrow	267	TON	\$15	\$4,000
Granular Borrow	990	TON	\$18	\$17,800
Untreated Base Course	291	TON	\$18.25	\$5,300
Hot Mix Asphalt	91	TON	\$56	\$5,100
Open Graded Surface Course	11	TON	\$80	\$900
			<u>Subtotal</u>	\$67,900
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$100,000	\$100,000
CEI Engineering	1	LUMP	\$6,800	\$6,800
Engineering	1	LUMP	\$6,800	\$6,800
			<u>Subtotal</u>	\$113,600
PROJECT TOTAL (CURRENT)				\$181,500
PROJECT TOTAL (2010)				\$220,800

**Staging Area Project Cost Estimate (2005)
East of Little Pine (Single Unit Truck) Option**

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
ROADWAY				
Mobilization	1	LUMP	\$13,900	\$13,900
Misc./Contingency	1	LUMP	\$20,900	\$20,900
Mitigation	1	LUMP	\$55,600	\$55,600
Borrow	3,230	TON	\$15	\$48,400
Granular Borrow	2,210	TON	\$18	\$39,800
Untreated Base Course	782	TON	\$18.25	\$14,300
Hot Mix Asphalt	553	TON	\$56	\$31,000
Open Graded Surface Course	69	TON	\$80	\$5,500
			<u>Subtotal</u>	\$229,400
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$100,000	\$100,000
CEI Engineering	1	LUMP	\$22,900	\$22,900
Engineering	1	LUMP	\$22,900	\$22,900
			<u>Subtotal</u>	\$145,800
PROJECT TOTAL (CURRENT)				\$375,200
PROJECT TOTAL (2010)				\$456,500

As shown in the four estimates above, the cost to improve a staging area is highly dependant upon the design vehicle and the local terrain and constraints. On the low end of the spectrum, improvements east of Little Pine to allow a passenger car to turn around are estimated to cost less than \$200,000. On the other end of the spectrum, improvements east of White Pine to allow a single unit truck to turn around are estimated to cost \$1.3 Million.

6. Tunnel Concept

6.1 *Tunnel Overview*

Tunnels have been constructed in Europe, Japan and Canada to avoid avalanche paths (Arlberg Pass, Austria; Mt. Blanc, France-Italy; Fluela, Gotthard and Lukmanier Passes, Switzerland; MacDonald Rail Tunnel, Roger's Pass, British Columbia).

SR-210 has received a grant for Scenic Byway status. Compatibility between Scenic Byway status and the tunnel concept is clearly an issue. Another issue is access to numerous trailheads, rock and/or ice climbing routes, campgrounds, and other properties along SR-210. Cost is a major factor. The tunnel concept is included at this preliminary level for comparison and to present a complete range of concepts.

The concept presented in this memorandum is for a tunnel from the park and ride lot at the base of the canyon to the end of the existing paved road. This 8 mile tunnel would provide two lanes, one in each direction. Portal locations were not considered beyond access to White Pine Trailhead, Snowbird lots 1 & 2, Snowbird Plaza, lower lot at Alta, and the end of the paved road.

Shorter tunnels to avoid certain sections of the road or specific avalanche paths are also a possibility. However, they were not evaluated for this memorandum.

6.2 *Tunnel Effectiveness*

A tunnel could practically eliminate avalanche hazard, depending on the location of access points.

6.3 *Right-of-Way*

The tunnel would pass beneath privately owned land as well as National Forest and potentially the Twin Peaks Wilderness Area.

6.4 *Tunnel Design*

In order to estimate costs for this concept, it was assumed the tunnel would be similar to the Wildwood Tunnels constructed for SR-189 in Provo Canyon (US-189: Provo Canyon, Upper Falls to Wildwood: Project No.*NH-0189(3)12). Two twin concrete lined tunnels were constructed to convey two lanes of traffic each.

6.5 Tunnel Cost Estimate

Unit Cost for Tunnel

The Wildwood Tunnels were bid in 1990 at a cost of \$11,296/ linear foot. The 2005 cost was estimated by applying Engineering News Record (ENR) escalation indices at \$17,700/linear foot.

Mobilization

Mobilization was estimated as 10% of the tunnel cost.

Misc./Contingency

Smaller construction costs and a contingency to cover unknowns were estimated together as 25% of the tunnel cost. Some examples of smaller construction costs could include lighting, drainage, signing and striping, ventilation, etc. Contingency costs could include encountering bedrock in excavation.

Mitigation

It was assumed that mitigating for environmental consequences could add an additional 15% to project costs. This corresponds to roughly 15% of the total estimated project cost.

Environmental Clearance

For cost estimating purposes only, it was assumed that the appropriate level of NEPA documentation would require an Environmental Impact Statement (EIS) and that costs for this level of documentation would be roughly \$2,000,000.

CEI

CEI (Construction Engineering Inspection) was estimated as 10% of the construction cost (mobilization, contingency, mitigation and tunnel structure).

Engineering Design

Engineering Design was estimated as 10% of the construction cost (mobilization, contingency, mitigation and tunnel structure).

Tunnel Project Cost Estimate

Estimated project costs are summarized in the table below. These unit costs assume the project could be bid in 2006. Assuming a 4% inflation rate per year, this estimate would increase to \$1,801,791,400 by 2010. It should be noted this estimate is very preliminary and should be used for planning purposes only.

Little Cottonwood Canyon Road (SR-210): Project No. SP-0210(4)4
Rough Cost Estimates for Avalanche Hazard Reduction Concepts

Tunnel Project Cost Estimate

Item Description	Quantity	Unit	Unit Cost	Amount
CONSTRUCTION				
Mobilization	1	LUMP	\$74,694,000	\$74,694,000
Misc./Contingency	1	LUMP	\$186,735,000	\$186,735,000
Mitigation	1	LUMP	\$224,082,000	\$224,082,000
Tunnel Structure	42,200	LIN. FT.	\$17,700	\$746,940,000
			<u>Subtotal</u>	\$1,232,451,000
NON CONSTRUCTION				
Environmental Clearance	1	LUMP	\$2,000,000	\$500,000
CEI Engineering	1	LUMP	\$123,245,100	\$123,245,100
Engineering	1	LUMP	\$123,245,100	\$123,245,100
			<u>Subtotal</u>	\$248,490,200
PROJECT TOTAL (CURRENT)				\$1,480,941,200
PROJECT TOTAL (2010)				\$1,801,791,400

INTERNAL F&P MEMORANDUM

Date: February 22, 2006
To: Jon Nepstad
From: Jeremy Klop AICP,
Aaron Heumann, P.E., P.T.O.E.

Subject: *Little Cottonwood Traffic Operations Analysis*

UT05-624

This memorandum summarizes the investigation of traffic operations in the Little Cottonwood canyon. Specific areas of analysis include mainline delay and avalanche hazard exposure during end of ski day peak periods and the relative benefits of traffic control alternatives at down valley entry points.

Existing Conditions

A VISSIM simulation of existing conditions was developed for comparison of traffic control alternatives. This simulation includes a number of simplifying assumptions and is intended to serve as a comparison point that is representative of observed conditions during the peak of exiting afternoon traffic. The model was calibrated to observed (snowing) conditions through changes to the default VISSIM values for the desired speed and headway, and the use of reduced speed areas to capture the effects of steep grades and slowing for sharp turns. The model was also specified to allow priority to driveway or entry access, since it was observed that mainline traffic commonly yields to entering traffic. While a modest amount of traffic was observed in the eastbound direction and from the minor access points along the corridor, analysis in the simulation is limited to outbound traffic on the mainline and four key intersections:

- Wildcat Base Lot
- Snowbird Entry 4
- Snowbird Entry 2
- Snowbird Entry 1

Traffic Control Alternatives

Both observed and simulated conditions suggest that the Snowbird Entry 1 intersection contributes to queues that build over time on the mainline due to the merging and yielding behavior of drivers at this location. In some cases, the mainline queue can extend all the way back to the Alta parking lots. This condition creates significant delay for mainline traffic and

increases the exposure time to avalanche paths that the mainline crosses. Accordingly, alternatives evaluated in the simulation are focused on this location.

The first alternative considered was signalization of this location. This would organize the merge condition at the Snowbird Entry and balance the flow of traffic to clear queues and avoid the long buildup of queues on a particular approach.

Based on the volume data provided by UDOT and collected between December 27 and 29, 2005, a signal warrant analysis suggests that a signal could be justified at the intersection of SR 210 and Snowbird Entry 1. The warrant analysis found that the intersection satisfies the criteria for the following three warrants:

- Warrant 1B: Interruption of Continuous Traffic, which is an eight hour volume warrant
- Warrant 2: Four-Hour Vehicular Volumes, applying the rural community standards
- Warrant 3: Peak Hour Volume, applying the rural community standards

In addition, we conducted a planning level evaluation of the impact of a traffic signal at the SR 210/Snowbird Entry 1 intersection might have on the operation of the surface parking lot that feeds onto the Snowbird Entry 1 roadway. We assumed a 60-second cycle for the signalized intersection operations and a split of 40 seconds of green time for SR 210 and 20 seconds of green time for the Snowbird Entry 1 approach. Taking into consideration lost time and start up time for a queue of vehicles, we calculated that the signal would be able to accommodate approximately 500 vehicles per hour for the Snowbird Entry 1 approach. The maximum volume reported from the tube counts for the Snowbird Entry 1 roadway was just over 350 vehicles in the peak hour, while the intersection turning movement counts reported a peak hour volume of less than 230 vehicles for the approach on Snowbird Entry 1. Both of these volumes are significantly below the capacity of 500 vehicles per hour.

The second alternative considered was conversion of the eastbound lane to a westbound, or outbound, lane in the peak afternoon time period. This treatment would allow outbound traffic at Snowbird Entry 1 to exit directly into the converted number two lane, avoiding the need to merge with mainline traffic. Stop control was assumed at the entry point. This alternative was analyzed for traffic operations and additional consideration of barriers, signage, driver information, and intersection design would be needed.

Simulation Findings

Intersection Delay

Analysis of delay for each approach at the four intersections evaluated show improved operations with both of the alternatives when compared to existing conditions. Table 1 shows the simulated delay and Level of Service (LOS) for each approach in each scenario.

Table 1. Delay Comparison

Entry	Existing		Signalized		Two-Lane Outbound	
	Delay	LOS	Delay	LOS	Delay	LOS
Wildcat Base - mainline	0.2	A	0.2	A	0.2	A
Wildcat Base - entry	5.3	A	5.3	A	5.3	A
Snowbird 4 - mainline	25.5	C	0.7	A	0.7	A
Snowbird 4 – entry	12.1	B	4.2	A	4.2	A

Snowbird 2 - mainline	81.4	F	4.9	A	4.9	A
Snowbird 2 – entry	276.6	F	5.1	A	5.0	A
Snowbird 1 - mainline	188.4	F	13.2	B	2.8	A
Snowbird 1 – entry	14.8	B	22.8	C	16.8	C

Queuing

Analysis of queuing for each approach of the four intersections evaluated also shows improved operations with both of the alternatives when compared to existing conditions. Table 2 shows the simulated queues for each approach in each scenario.

Table 2. Queue Comparison

Entry	Existing		Signalized		Two-Lane Outbound	
	Avg. Queue (ft)	Max. Queue (ft)	Avg. Queue (ft)	Max. Queue (ft)	Avg. Queue (ft)	Max. Queue (ft)
Wildcat Base - mainline	0	0	0	0	0	0
Wildcat Base - entry	2	46	2	46	2	45
Snowbird 4 - mainline	47	235	0	45	0	41
Snowbird 4 – entry	0	0	0	0	0	0
Snowbird 2 - mainline	1450	1656	5	128	5	125
Snowbird 2 – entry	9	219	0	13	0	16
Snowbird 1 - mainline	1589	1656	31	272	16	244
Snowbird 1 – entry	9	219	22	56	0	0

Travel Time

In addition to the delay comparison, a travel time analysis was completed for each scenario to quantify the relative exposure to avalanche hazards. Since queues build in the existing conditions model, a long travel time segment was defined. Travel time is measured from a point just west of Hellgate to a point just west of the Snowbird 1 entry. This segment includes some of the most hazardous avalanche paths and captures the majority of the mainline queuing. Table 2 shows the travel time and average speeds for each scenario. Analysis of travel time suggests that either alternative could reduce average travel times and increase average travel speeds in this segment of the canyon.

Table 2. Travel Time Comparison

Scenario	Travel Time (min.:sec.)		Speed (mph)
	Average	Std. Dev.	Average
Existing	26:34	01:49	3.7
Signalized	08:09	00:07	12.1
Two-Lane Outbound	07:57	00:06	12.4